Inventor: Bruce D. Holenstein
Attorney Docket No. 9203-27U1
Express Mail Label No. EV312207249US

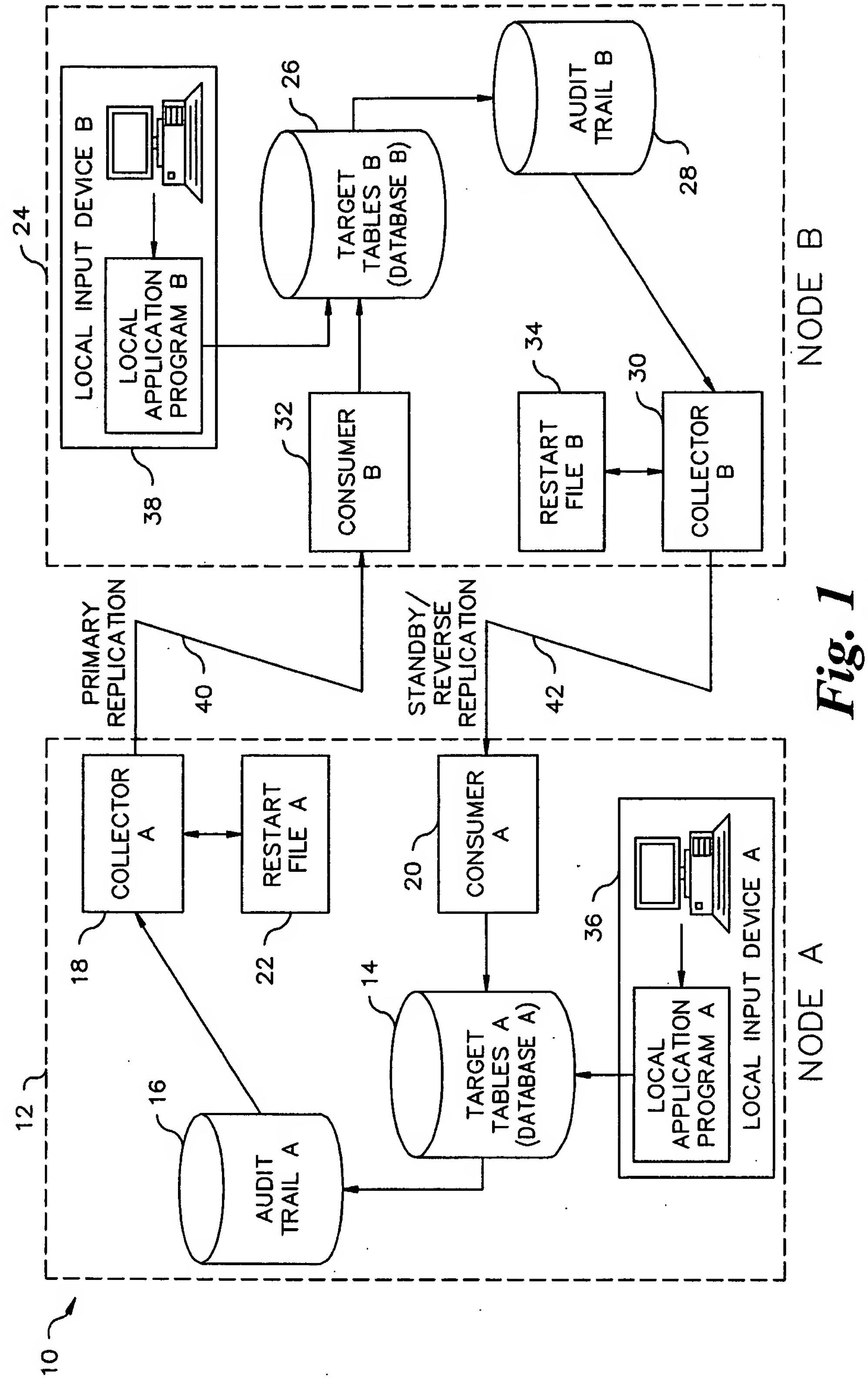


Fig. 1
(Prior Art)

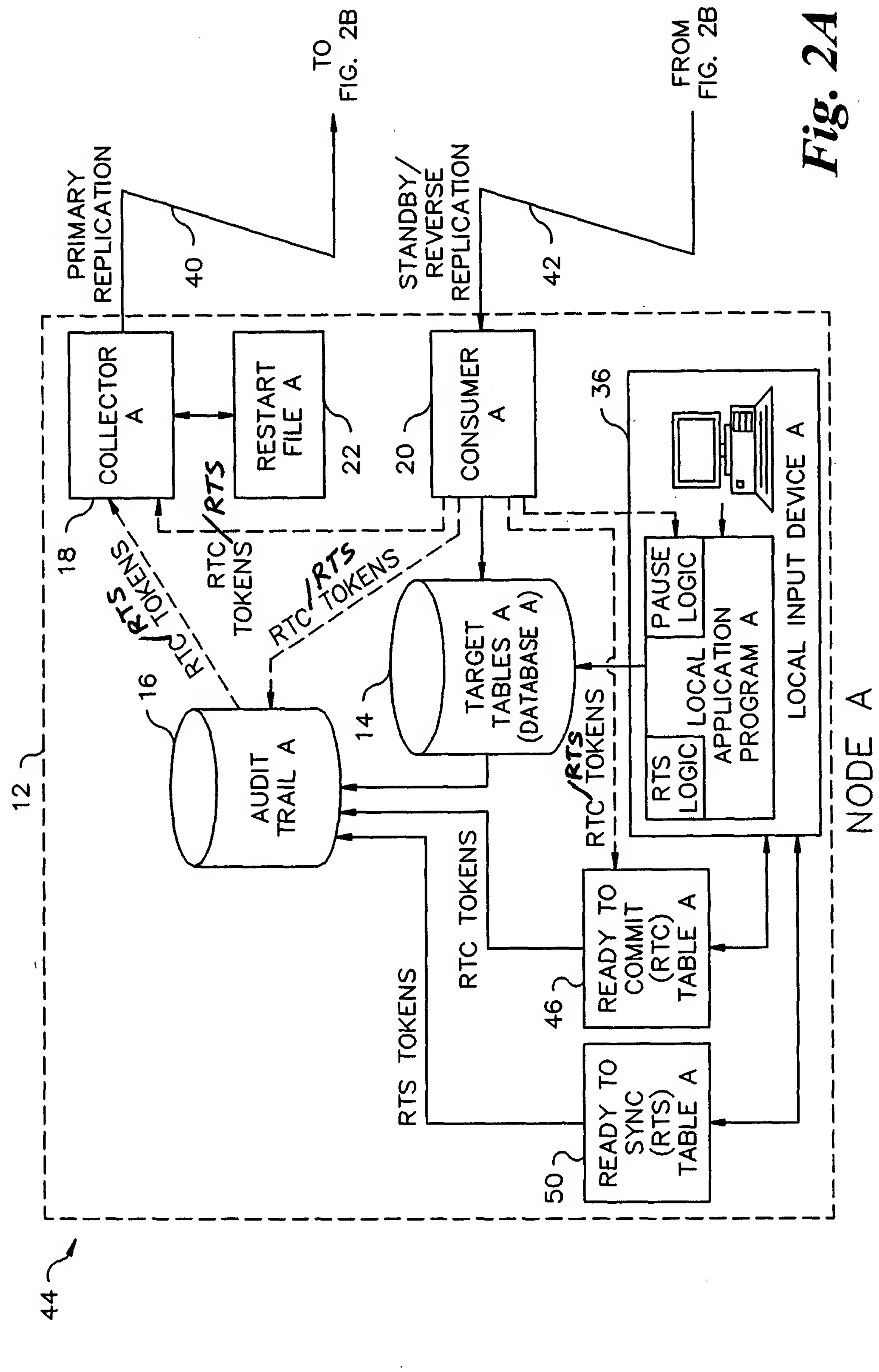
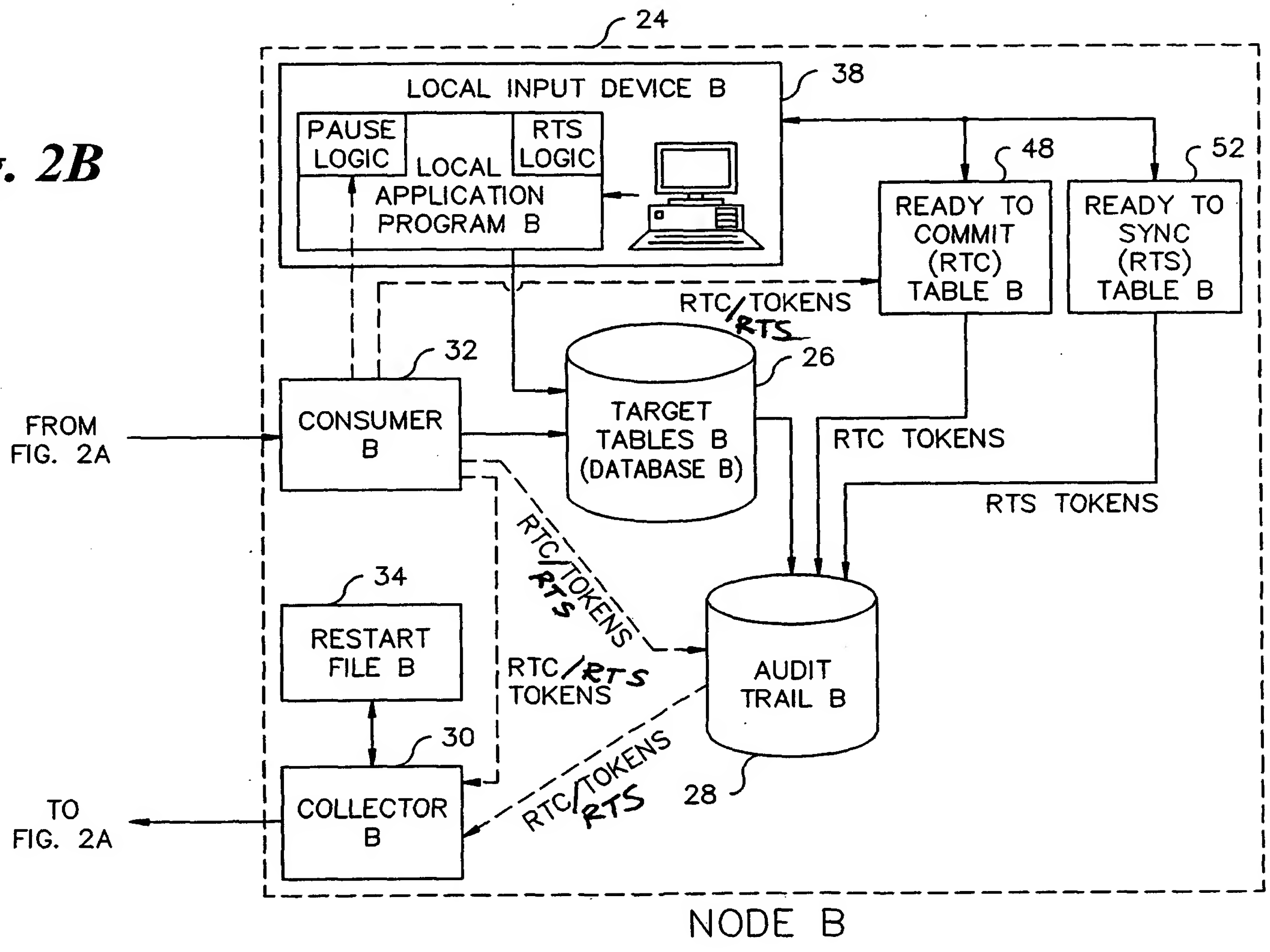

44
12
NODE A
PRIMARY REPLICATION
40
TO FIG. 2B
STANDBY/ REVERSE REPLICATION
42
FROM FIG. 2B
COLLECTOR A
18
RESTART FILE A
22
CONSUMER A
20
36
LOCAL INPUT DEVICE A
PAUSE LOGIC
RTS LOGIC
LOCAL APPLICATION PROGRAM A
RTC/RTS TOKENS
RTC/RTS TOKENS
RTC/RTS TOKENS
RTC/RTS TOKENS
AUDIT TRAIL A
16
TARGET TABLES A (DATABASE A)
14
RTC TOKENS
RTS TOKENS
READY TO COMMIT (RTC) TABLE A
46
READY TO SYNC (RTS) TABLE A
50

Fig. 2A

Fig. 2B


24
LOCAL INPUT DEVICE B
38
PAUSE LOGIC
LOCAL APPLICATION PROGRAM B
RTS LOGIC
48
52
READY TO COMMIT (RTC) TABLE B
READY TO SYNC (RTS) TABLE B
RTC/TOKENS
RTS
32
26
FROM FIG. 2A
CONSUMER B
TARGET TABLES B (DATABASE B)
RTC TOKENS
RTS TOKENS
RTC/TOKENS
RTS
34
RESTART FILE B
RTC/RTS TOKENS
AUDIT TRAIL B
30
28
TO FIG. 2A
COLLECTOR B
RTC/TOKENS
RTS
NODE B

RTC TABLE A

TIME	CONTENTS	
	TRAN ID	FLAG
t_1		
t_2		
t_3		
t_4	101	0
t_5	101	1
t_6	*	
•		
•		
•		
t_n		

* NO ENTRY
(TRAN ID 101
HAS BEEN
DELETED
FROM TABLE)

AUDIT TRAIL A

TIME	HEADER		DATA
	TRAN ID	TABLE	
t_1	101		BEGIN TRANS. 101
t_2	101	ACCOUNTS	SMITH, JOHN, DEBIT $10
t_3	101	ACCOUNTS	DOE, JANE, CREDIT $10
t_4	101		RTC TOKEN 101
t_5			
t_6	101		COMMIT TRANS. 101

AUDIT TRAIL B

TIME	HEADER		DATA
	TRAN ID	TABLE	
$t_1+\alpha$	101		BEGIN TRANS. 101
$t_2+\alpha$	101	ACCOUNTS	SMITH, JOHN, DEBIT $10
$t_3+\alpha$	101	ACCOUNTS	DOE, JANE, CREDIT $10
$t_4+\alpha$	101		RTC TOKEN 101
$t_5+\alpha$			
$t_6+\alpha$	101		COMMIT TRANS. 101

Fig. 3

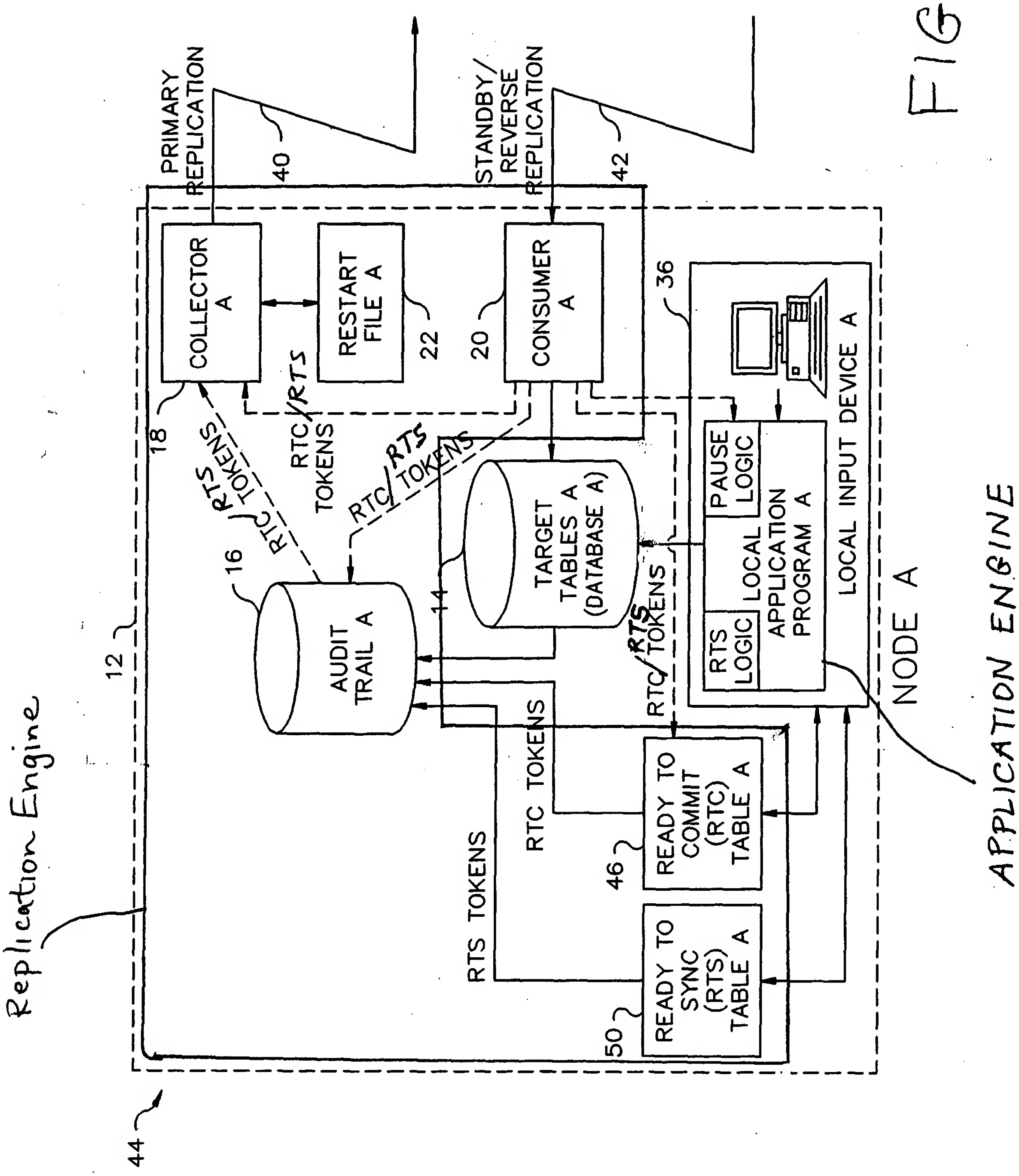

PRIMARY REPLICATION
40
STANDBY/ REVERSE REPLICATION
42
COLLECTOR A
RESTART FILE A
22
20
CONSUMER A
36
18
RTC/RTS TOKENS
RTC/RTS TOKENS
RTC/RTS TOKENS
16
AUDIT TRAIL A
14
TARGET TABLES A (DATABASE A)
RTC/RTS TOKENS
PAUSE LOGIC
RTS LOGIC
LOCAL APPLICATION PROGRAM A
LOCAL INPUT DEVICE A
NODE A
12
RTC TOKENS
READY TO COMMIT (RTC) TABLE A
46
RTS TOKENS
READY TO SYNC (RTS) TABLE A
50
44
Replication Engine
APPLICATION ENGINE

FIG. 4

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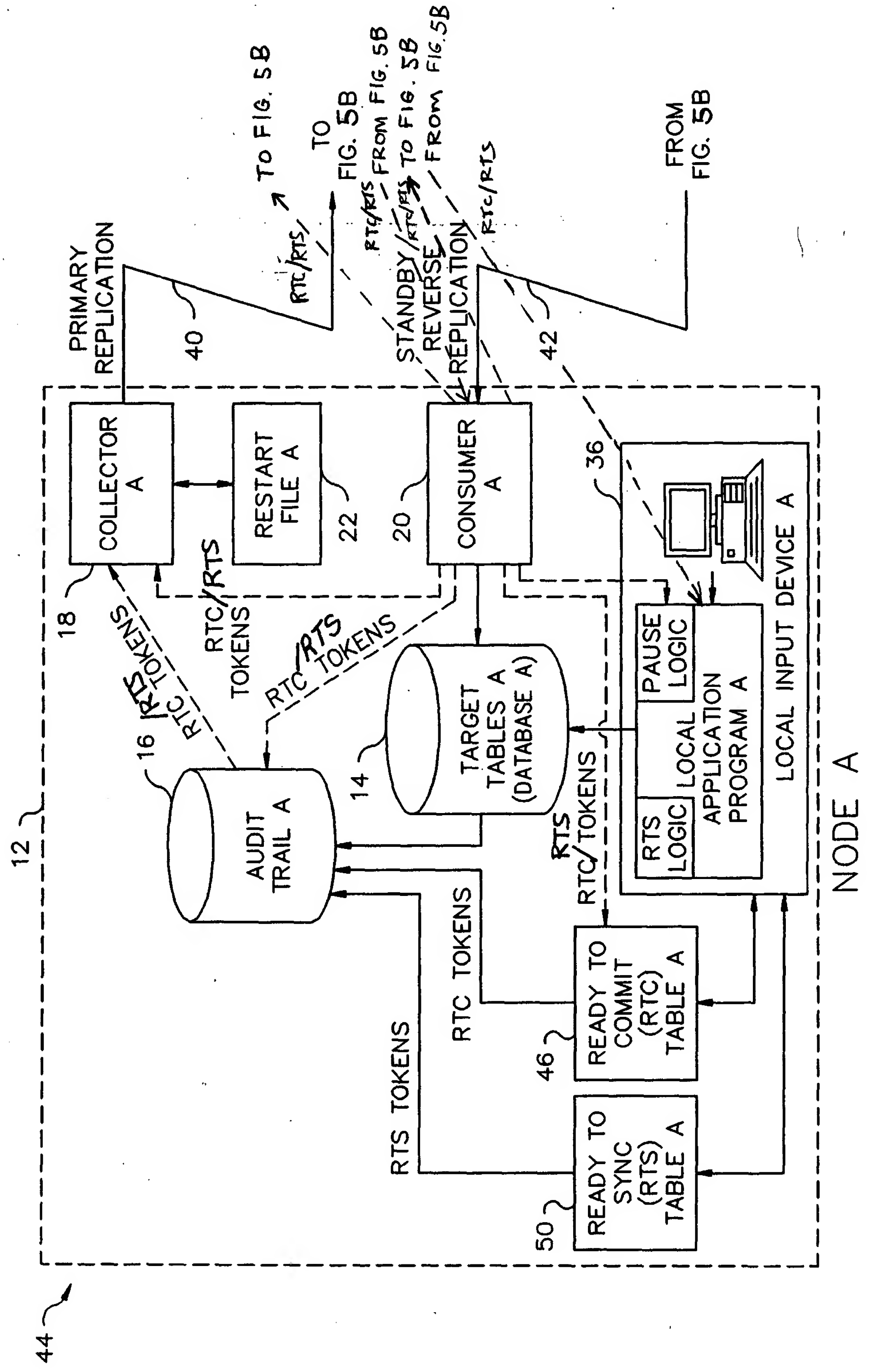
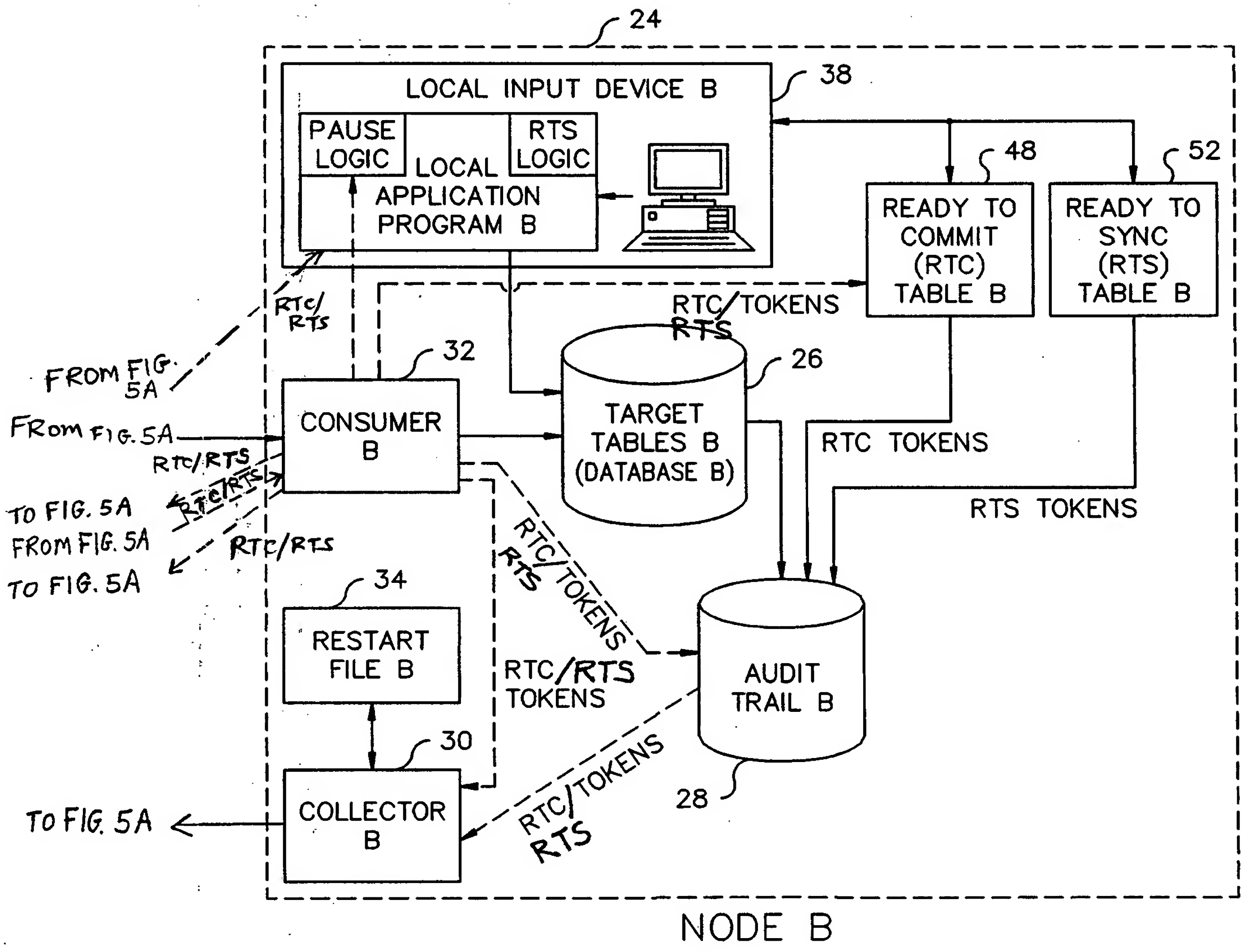


FIG. 5A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LOCAL INPUT DEVICE B
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PAUSE LOGIC
LOCAL APPLICATION PROGRAM B
RTS LOGIC
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READY TO COMMIT (RTC) TABLE B
52
READY TO SYNC (RTS) TABLE B
RTC/TOKENS
RTS
26
TARGET TABLES B (DATABASE B)
RTC TOKENS
RTS TOKENS
32
CONSUMER B
RTC/RTS
FROM FIG. 5A
FROM FIG. 5A
RTC/RTS
RTC/RTS
TO FIG. 5A
FROM FIG. 5A
RTC/RTS
TO FIG. 5A
RTC/TOKENS
RTS
RTC/RTS TOKENS
AUDIT TRAIL B
34
RESTART FILE B
30
COLLECTOR B
TO FIG. 5A
RTC/TOKENS
RTS
28
NODE B

FIG. 5B

Title: Asynchronous Token-Based Data Rep...
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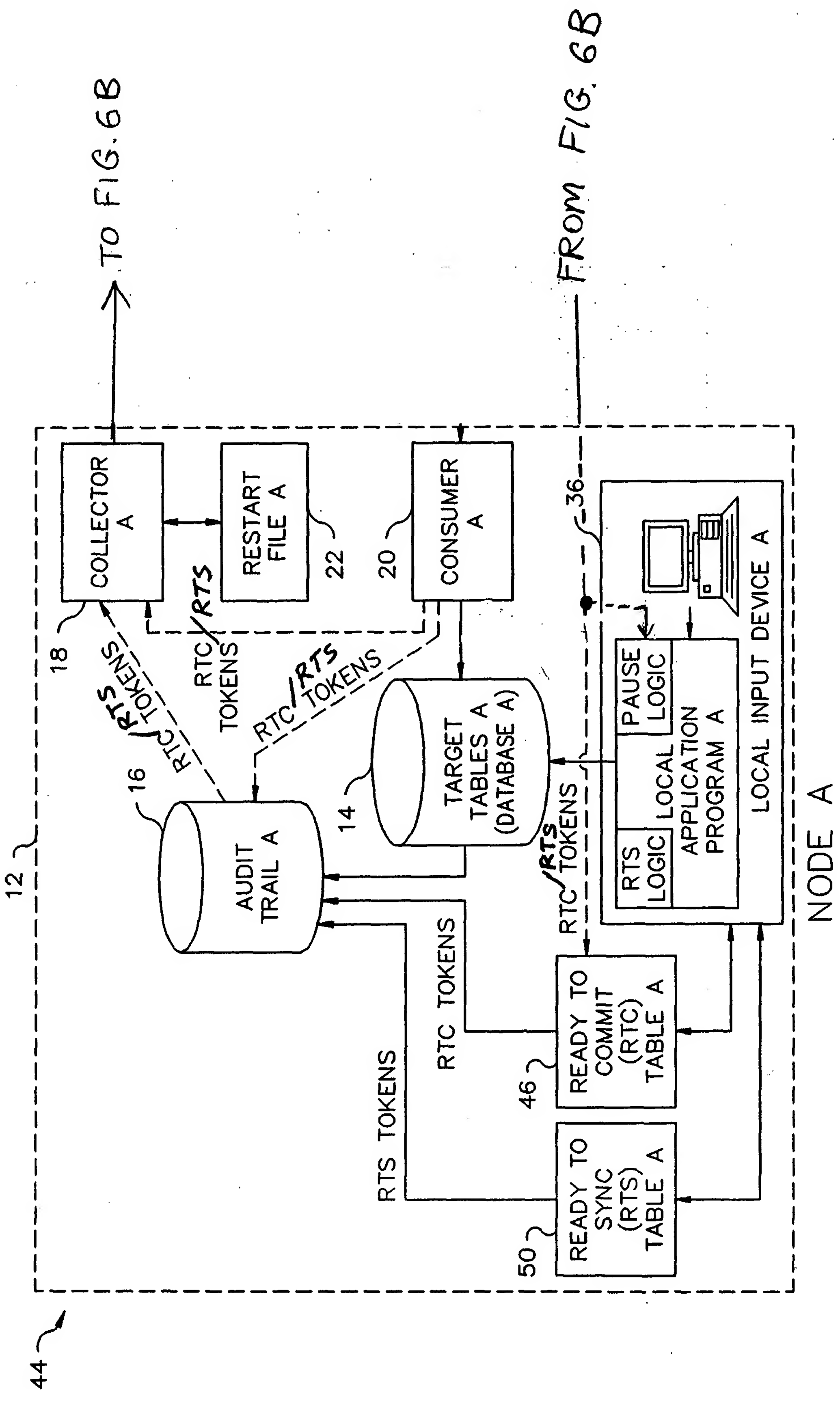
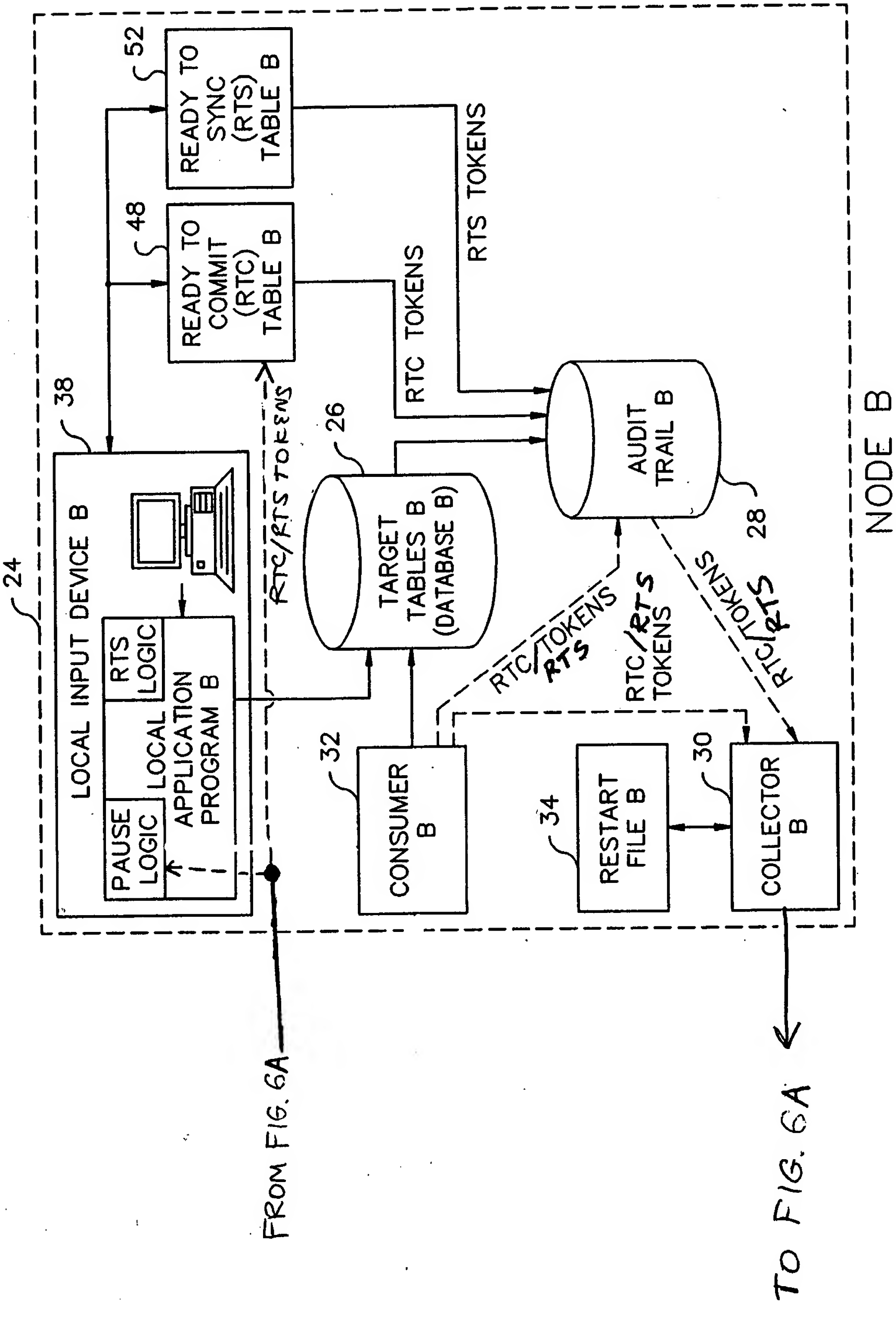


FIG. 6A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LOCAL INPUT DEVICE B
38
PAUSE LOGIC
LOCAL APPLICATION PROGRAM B
RTS LOGIC
READY TO COMMIT (RTC) TABLE B
48
READY TO SYNC (RTS) TABLE B
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RTC/RTS TOKENS
RTC TOKENS
RTS TOKENS
TARGET TABLES B (DATABASE B)
26
AUDIT TRAIL B
28
CONSUMER B
32
RTC/TOKENS RTS
RTC/RTS TOKENS
RTC/RTS TOKENS
RESTART FILE B
34
COLLECTOR B
30
NODE B
FROM FIG. 6A
TO FIG. 6A

FIG. 6B

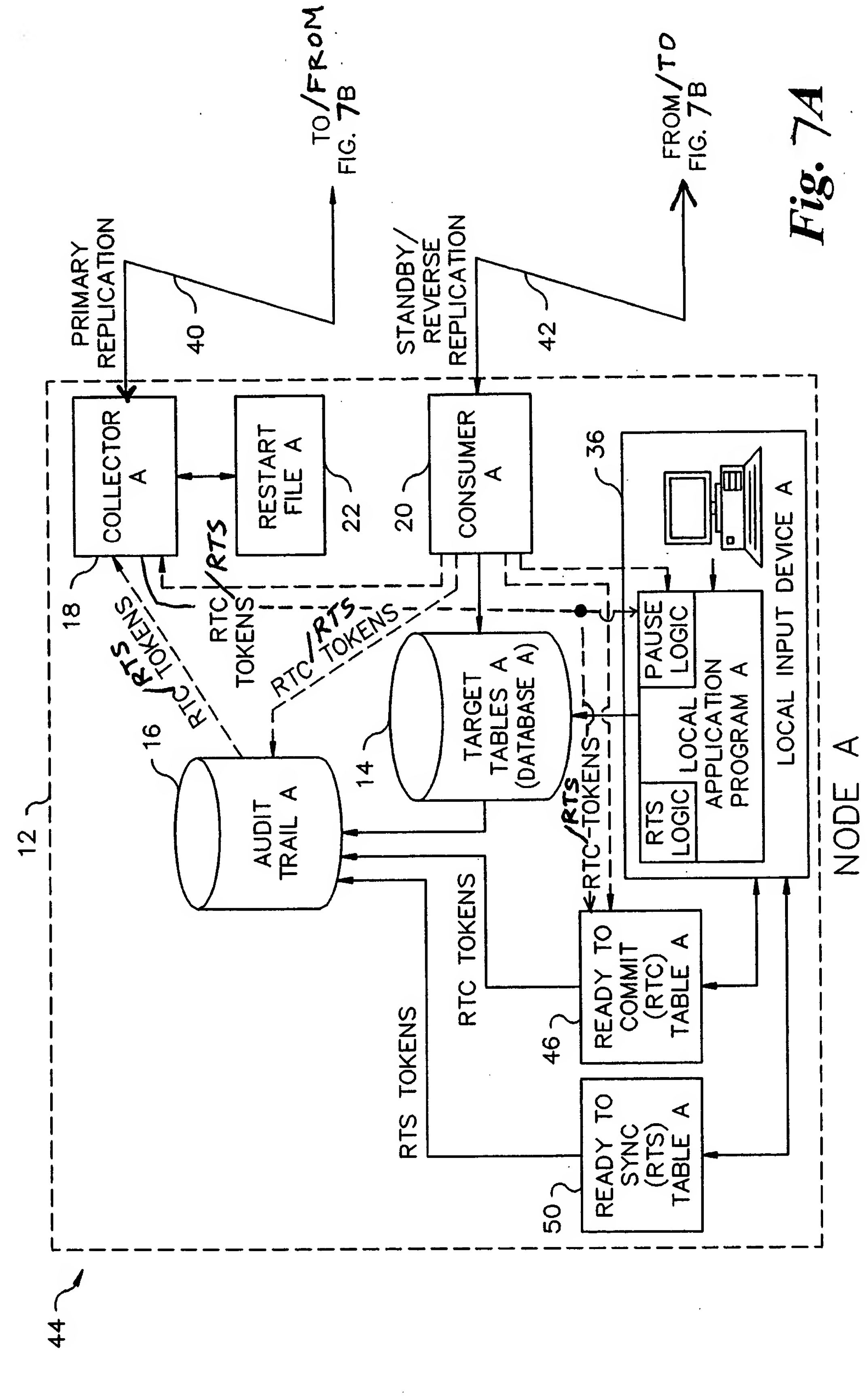

44
12
NODE A
COLLECTOR A
18
RESTART FILE A
22
CONSUMER A
20
PRIMARY REPLICATION
40
TO/FROM FIG. 7B
STANDBY/REVERSE REPLICATION
42
FROM/TO FIG. 7B
AUDIT TRAIL A
16
TARGET TABLES A (DATABASE A)
14
RTC/RTS TOKENS
RTC/RTS TOKENS
RTC/RTS TOKENS
RTC/RTS TOKENS
RTC TOKENS
RTS TOKENS
READY TO COMMIT (RTC) TABLE A
46
READY TO SYNC (RTS) TABLE A
50
RTS LOGIC
LOCAL APPLICATION PROGRAM A
PAUSE LOGIC
LOCAL INPUT DEVICE A
36

Fig. 7A

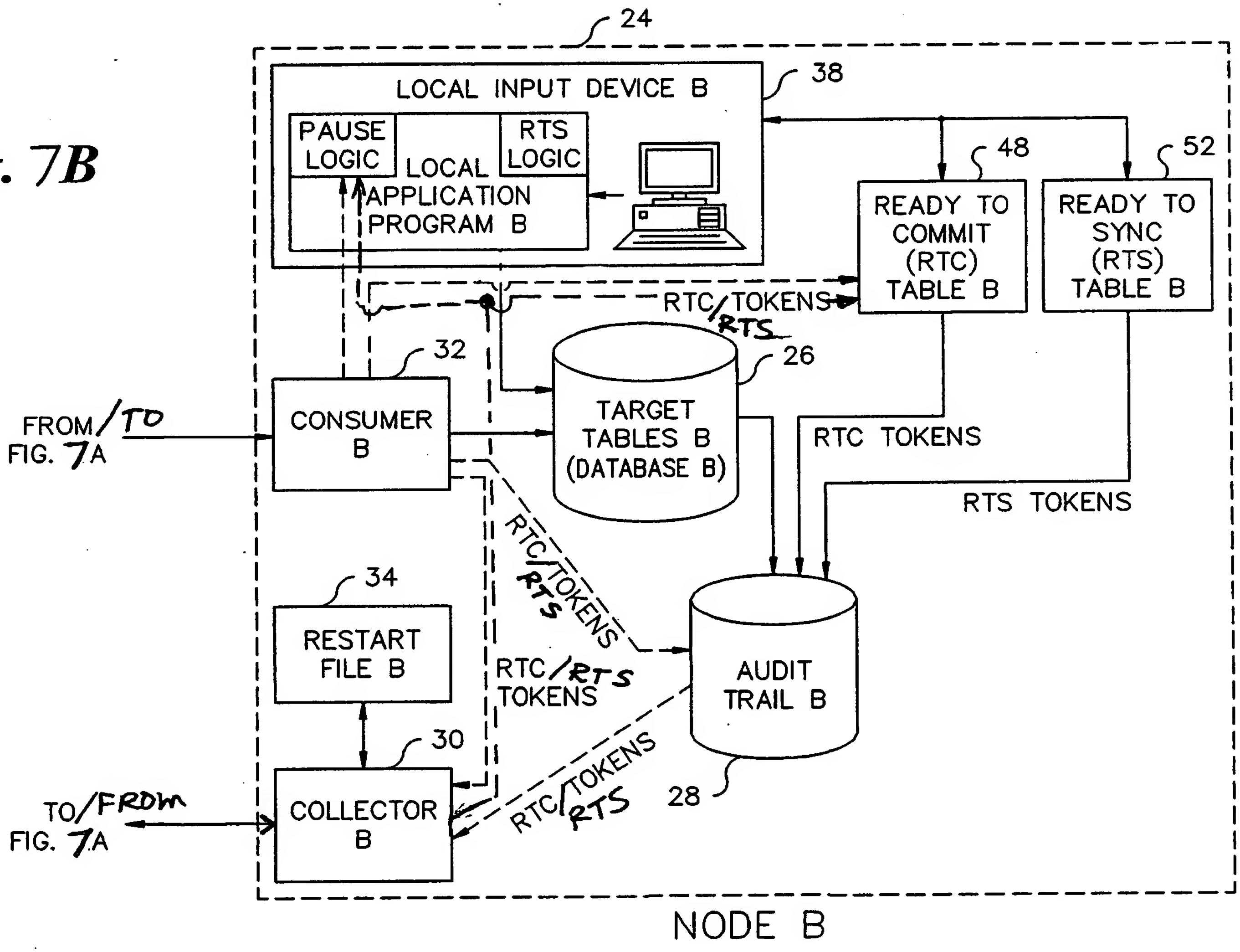
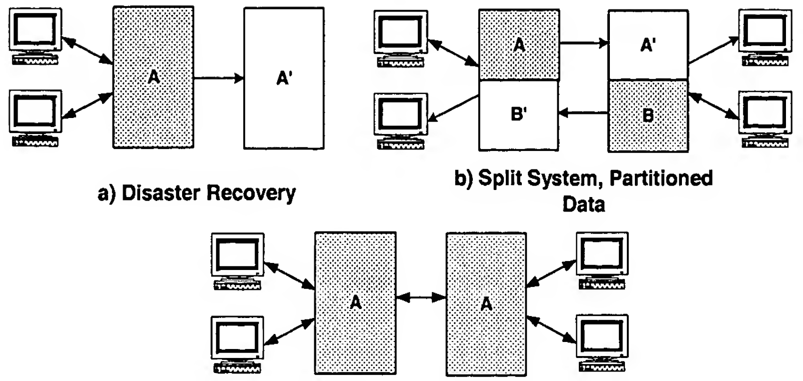

24
LOCAL INPUT DEVICE B
38
PAUSE LOGIC
RTS LOGIC
LOCAL APPLICATION PROGRAM B
48
READY TO COMMIT (RTC) TABLE B
52
READY TO SYNC (RTS) TABLE B
RTC/TOKENS
RTS
32
26
FROM/TO
FIG. 7A
CONSUMER B
TARGET TABLES B (DATABASE B)
RTC TOKENS
RTS TOKENS
RTC/TOKENS
RTS
34
RESTART FILE B
RTC/RTS
TOKENS
AUDIT TRAIL B
30
28
TO/FROM
FIG. 7A
COLLECTOR B
RTC/TOKENS
RTS
NODE B

Fig. 7B

Node	Time	Transaction amount	Comments
A, B	T1		Account balance initially at $1000, both nodes A and B synchronized.
A, B	T2	+$200	Customer deposits (adds) $200 to account balance from node A. Using the synchronous replication method, both nodes are updated to a balance of $1200
A, B	T3	-$75	Customer withdrawals (subtracts) $75 from the account balance from node B. Using the synchronous replication method, both nodes are updated to a balance of $1125
A, B	T4	-$125	Customer transfers (subtracts) $125 from the account balance to a foreign account from node A. Using the synchronous replication method, both nodes are updated to a balance of $1000
	T5		All communications between nodes A and B is lost. A = B = $1000
A	T6	+$100	Customer adds $100 to account balance on node A. A balance = $1100, B balance = $1000
B	T7	-$50	Customer withdrawals $50 from account balance on node B. A node balance = $1100, B node balance = $950.
A, B	T8		Full communications is restored, and the system resolves collisions as follows: A replays the transaction delta changes into B, B replays the transaction delta changes into A. The order of replay could be arbitrary. One could even 'merge' the two replay streams, using timestamps or sequence numbers, etc. The main point is that the account balances will match after all are replayed into the others.
A -> B	T9	+100	More specifically, replaying the A transactions to the B database adds $100 to the B balance of $950, making it $1050. NOTE – we could be done by simply overwriting the A database balance with the B database balance, however replaying in the reverse provides a 'check' of the approach.
B -> A	T10	-50	Replaying the B transactions to the A database subtracts $50 from the A balance of $1100, making it $1050.
A, B	T11		Compare the two balances, A=B and the databases are in sync. If other criteria are met, synchronous replication can be resumed.

Figure 8



a) Disaster Recovery

b) Split System, Partitioned Data

c) Split System, Shared Data

Split System Architectures

Fig. 9

Title: Asynchronous Token-Based Data Replication . . . Only
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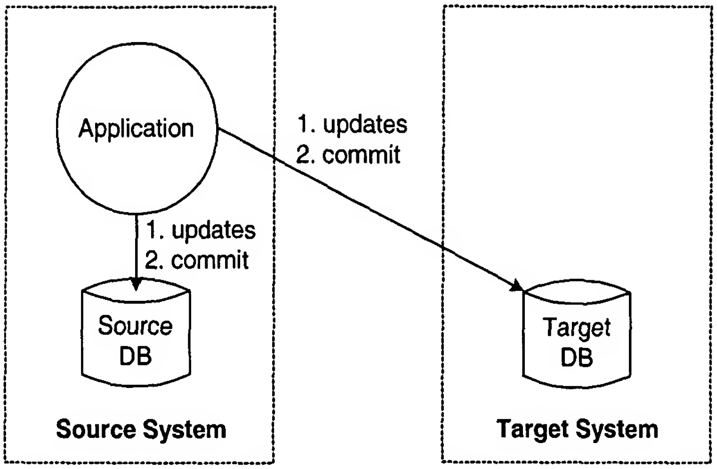

Dual Writes

Fig. 10

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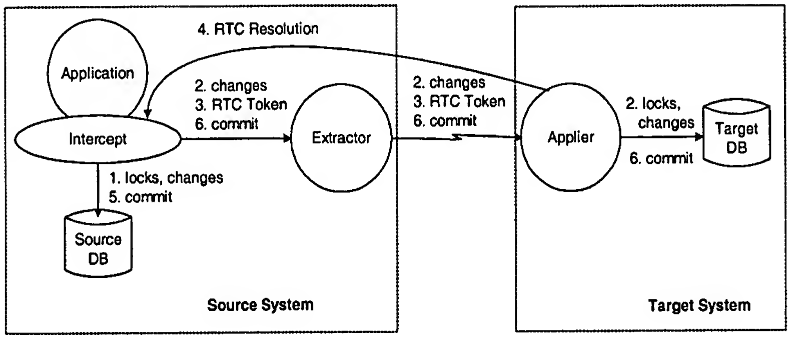
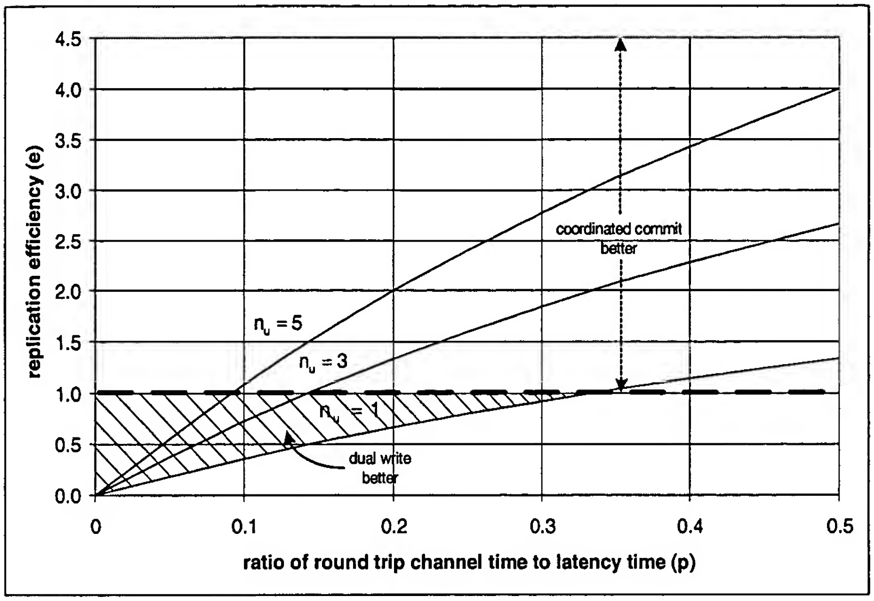


Coordinated Commits

Fig. 11



Synchronous Replication Efficiency

Fig. 12

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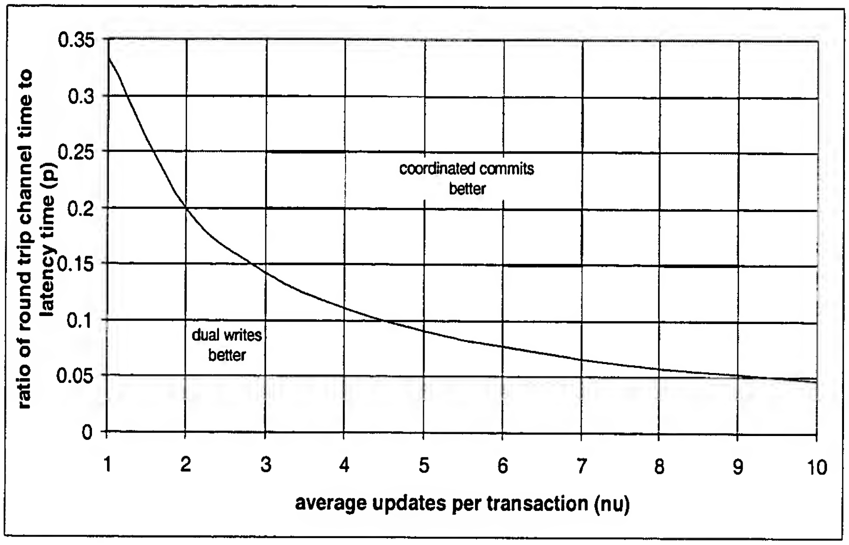
Express Mail Label No. EV312207249US



Equal Efficiency (e=1)

Fig. 13